MILK ANALYSIS

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A PRACTICAL TREATISE

ON THE

EXAMINATION OF MILK AND ITS DERIVATIVES,
CREAM, BUTTER, AND CHEESE.

BY

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PREFACE TO THE FIRST EDITION.

DURING the year 1871 I devoted much attention to the subject of milk-analysis, and besides making many hundreds of analyses of milk purchased in different parts of London for the *Milk Journal*, was employed by Government in an investigation into the milk supplied to the Metropolitan Workhouses. I have likewise examined the milk supplied to the Hospitals in London.

In the course of this work, I have been fortunate enough to make some improvements in the art of milk-analysis, and, in particular, some little modifications in the taking of milk-residues, so as to transfer such determinations (which before were tedious and uncertain) into the list of the simplest and most exact of chemical analyses. At the present time, when a new class of men has been constituted to watch over the food of the country, there is need for special manuals of this description.

LONDON, *November* 1873.

PREFACE TO THE SECOND EDITION.

THE Second Edition of this book is the First Edition, *plus* some additions, and with a few clerical errors corrected.

2d January 1886.

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MILK-ANALYSIS.

CHAPTER I.

INTRODUCTORY.

Milk, which is the secretion of the mammary glands, and constitutes the entire food and drink of the young mammal, is an aqueous solution of caseine, milk-sugar, and small quantities of mineral material, and holds in suspension a quantity of fat in a state of fine subdivision.

The milk of the cow, to which we shall confine our attention in this work, has been analysed at various times by many chemists. My own analyses, which are among the most recent, are as follows:—

In 100 cubic centimeters of average country milk I found—

Water	90·09	grammes.
Fat	3·16	„
Caseine	4·16	„
Milk-sugar	4·76	„
Ash	0·73	„
	102·90	

Town-fed milk is a little richer. According to my analysis, it contains in 100 cubic centimeters—

Water	88·43	grammes.
Fat	4·12	,,
Caseine	5·16	,,
Milk-sugar . . .	4·43	,,
Ash	0·76	,,
	102·90	

I have likewise made an analysis of the milk of the Alderney cow, which, notwithstanding the popular prejudice in its favour, as will be seen, does not much differ from other milk. I found in 100 cubic centimeters of such milk—

Water	89·88	grammes.
Fat . . .	3·31	,,
Caseine	4·75	,,
Milk-sugar . . .	4·24	,,
Ash	0·72	,,
	102·90	

The water which enters into the constitution of milk may be extracted from it by evaporation, and, that having been done, there will remain behind the *milk-solids*, which consist of the fat, caseine, milk-sugar, and ash (or mineral matters) conjointly.

The fat exists in milk in the form of very minute globules. It is not a single chemical substance, but a mixture of chemical substances. It consists of olein, palmitin, stearin, and small quantities of butyrin and other fats. All these different fatty substances are ethers of glycerine, and are capable of yielding glycerine when digested with alkalis, yielding at the same time the corresponding alkaline salt. Thus when the fat of milk is digested with potash or soda, it furnishes glycerine, and, at the same time, the oleate, palmitate, stearate, and butyrate of potash or soda. The fat of milk is hard at winter temperatures, and soft at summer temperatures (its fusing-point lying, in fact, at such temperatures as are reached in summer). Fat is distinguished from the other solid constituents of milk by being soluble in ether.

Caseine.—This is the nitrogenous constituent of milk. In regard to this portion of the milk, the remark should first be made that it is not perfectly homogeneous—that is to say, there are at least two distinct chemical substances comprised by the nitrogenous portion of milk.

There is caseine proper, and also albumen—that is to say, a certain proportion of the nitrogenous substance is coagulated on boiling milk, but the major part of the nitrogenous substance is not coagulated on boiling. Whether the portion of nitrogenous substance which is not coagulated on boiling is itself homogeneous, is even a matter of some doubt. In a corresponding case—that of flour—we know that the nitrogenous constituent is a very complex mixture, and that, under the name of gluten, a whole tribe of substances are comprehended. Under the name of caseine it will be convenient to designate the entire nitrogenous constituents of milk; just as, under the name gluten, the entire nitrogenous portion of flour is comprehended. Like albumen, caseine exists under two modifications—it is either soluble or insoluble. In the former of these states it exists in fresh milk; in the latter, after the milk has "turned."

It used to be believed that the soluble variety of caseine was in reality a salt of caseine, wherein caseine played the part of acid, and the alkali naturally present in milk-ash played the part of base. The coagulation or curdling of milk was explained on the supposition that lactic acid, generated by incipient fermentation of the milk-sugar, decomposed this hypothetical compound, and threw down insoluble caseine.

This explanation must be abandoned, inasmuch as investigation has shown that the ash of milk is almost absolutely devoid of alkali. In truth, we are driven to the conclusion, that the change from soluble to insoluble caseine is molecular, resembling the change from soluble silica to insoluble silica.

The ultimate composition of caseine is not distinguishable from that of albumen and fibrine, viz.—

Carbon	53·7
Hydrogen . . .	7·1
Nitrogen . . .	15·7
Oxygen	23·5
	100·0

There is likewise a trace of sulphur, said to be about one per cent. In milk the caseine is chemically combined with phosphate of lime; and there is no known method of effecting a separation between the two without destroying the caseine.

Milk is coagulated—that is to say, the caseine is rendered insoluble—by the action of rennet, of acid, and of many metallic salts.

Caseine which has become insoluble in water is redissolved by alkalis, and also by solution of phosphate of soda.

Milk-sugar, $C_{12}H_{22}O_{11}H_2O$.—This substance may be obtained from milk by coagulating the caseine and removing that along with the fat, and then evaporating the residual liquid (or whey) to crystallisation. The crystals are decolourised by means of animal charcoal. It is distinguished from cane-sugar in various ways.

In composition. When dried at 100° Cent., milk-sugar has the formula as given above, viz., $C_{12}H_{22}O_{11}H_2O$; cane-sugar, on the contrary, when dried at 100° Cent., exhibits the composition $C_{12}H_{22}O_{11}$. Heated to about 140° Cent., milk-sugar loses an atom of water, and becomes $C_{12}H_{22}O_{11}$.

In solubility in water there is much difference between the two. Milk-sugar dissolves in five or six parts of cold water and in two and a half parts of boiling water. Cane-sugar, on the other hand, is far more soluble. It dissolves in one-third of its volume of cold water, and in exceedingly little boiling water.

Milk-sugar is not so heavy as cane-sugar, its specific gravity being 1·53; whilst cane-sugar has a specific gravity of 1·606.

Towards alkaline-copper-solution, the behaviour of the two kinds of sugar is quite different; whereas milk-sugar reduces the oxide to the suboxide of copper even in the cold, solution of cane-sugar does not even effect a reduction on being heated to the boiling point of water.

The Ash, or Mineral Matter.—When milk is dried up, and the dried residue afterwards incinerated, the ash remains behind. This consists mainly of phosphate of lime, which forms about two-thirds of it, and of chlorides. There is hardly any free or carbonated alkali in the ash of cow's milk. The degree of freedom of the ash from alkali may be judged of from the fact, ascertained by myself, that the ash does not neutralise as much standard acid as it would if one-hundredth of its weight consisted of alkaline-carbonate.

Such, then, are the component parts of milk. It remains to be added, that milk has a specific gravity of about 1·029, at 15·6 C., and that its physical appearance is very peculiar. It is not a clear liquid, being, in point of fact, an emulsion. Left to itself, it by-and-by becomes surmounted with a whitish layer, well known as cream. When fresh, it is very nearly neutral to test-paper, but is very apt to turn sour from very slight causes.

Milk exhibits great constancy of composition; the effect of variations in the diet of the cow showing itself in the amount of the secretion rather than in its quality. This is very strikingly manifested on making a comparison of the milk yielded by the poor and ill-fed Bengali cow in India with that given by our own highly-fed beasts in this country. Dr. Macnamara's analyses of the milk of the Bengali cows show that it hardly differs from the milk of English cows in quality, whereas in quantity it differs greatly, the yield of milk from the former being a small fraction only of that from the latter. The milk of an animal has probably very much the same constancy of composition as the blood of the animal. It is well known that, by administering water to an animal, we are not able to dilute its blood to any considerable extent. Instead of telling on the blood, the water tells on the perspiration or on the urine, so that from containing four or five per cent. of solids, the urine may become so dilute as to contain only one per cent. of solids. The milk resembles the blood in this respect, and is in contrast with the urine; and by giving an animal an excess of water, we do not dilute its milk, but its urine.

As will be readily comprehended, this constancy of composition is a cardinal fact in milk analysis. If milk were variable in strength, as urine is, chemical analysis would fail to detect the watering of milk. That milk is a secretion of constant, or only slightly varying composition, lies at the very root of the subject of this treatise.

In Chapter IX., on "*The Milk Supply of the London Workhouses*," the experimental evidence bearing upon this question is minutely entered into.

Since the publication of the first edition of this book my views have advanced. The opening sentence of the book, in which I wrote "is an aqueous solution of caseine, milk-sugar," &c., I should alter into "is an aqueous solution *yielding* caseine, milk-sugar, and small quantities of mineral material."

I suspect that milk contains neither caseine nor milk-sugar ready formed, and that the caseine and milk-sugar are products of the breaking up of a complex substance, caseo-lactine.

CHAPTER II.

INSTRUMENTS AND METHODS FOR TESTING MILK—OUTLINE OF MILK-ANALYSIS.

THE *lactometer*, or *lactodensimeter*, as it has been called, to distinguish it from another simple instrument, the creamometer, was at one time a great favourite. In France, a few years ago, if not indeed now, the police would take action at once on a reading of that instrument, and turn milk out into the gutter if it were condemned. And in London, the lactometer is exposed for sale in shop windows, and both the public and milk dealers trust to it. Even in some recent manuals intended for the guidance of medical officers of health, the use of the lactometer is recommended. In one of them in particular—Dr. Edward Smith's—which claims a sort of pseudo-government sanction, the lactometer is very prominently put forward, and commended as being for milk what the hydrometer is for alcoholic fluids.

But, although it is so very popular, and although it has been so implicitly trusted, the lactometer is a most untrustworthy instrument. There hardly ever was an instrument which has so utterly failed as the lactometer. It confounds together milk which is exceptionally rich with milk which has been largely watered; and many a poor French peasant, bringing the best and unadulterated produce of his dairy into a French town, has been ruthlessly stopped by the police, who have dipped their lactometer into the milk, and forthwith sent it down the gutter, as if it had been milk and water.

Very curious things, too, are done in this country by reason of trust in the lactometer. There is a prison not far from London, and the prison authorities are specially particular about their supply of milk. They allow no milk to enter the prison unless it comes up to the M. mark on a certain lactometer. The M. mark is pitched very high, and the milk purveyor reaches the M. mark by skimming the milk.

A very little consideration will suffice to make intelligible the obliquity of the indications of the lactometer, and to show how untrustworthy it must be. The lactometer, as, of course, will be understood, is simply the hydrometer applied to milk; and readings of the instrument are neither more nor less than specific gravities. The more milk-sugar and caseine and mineral matter there is in a given specimen of milk, the greater (other things being equal) will be its density or specific gravity, and the higher the lactometer reading.

If, however, fat globules (as happens in the instance of milk) be diffused through the fluid, then, because fat is lighter than water, the effect of the other milk-solids on the gravity of the liquid will be more or less neutralised. The density of milk-fat is about 0·9, water being 1·0. Now, if a solution of caseine and milk-sugar, of specific gravity 1·030, be sufficiently charged with fat globules, its specific gravity may be sent down even below the gravity of water. How much would be required to bring about such a result is a matter of simple calculation.

This being understood, it will be obvious that if the specimens of milk differ in specific gravity, there must be two distinct and equally valid ways of accounting for the difference. The milk with the lower gravity may be milk let down with water, or let down with fat, *i.e.*, milk let down by being enriched.

By way of example, I would just refer to the specific gravity of the so-called strippings, which are the last portions of milk wrung out of the udder at the termination of the milking. These are richer in cream than the average mass of the milk, and they have a much lower density than average milk.

I have myself examined strippings with a specific gravity of 1·020, and a specific gravity of 1·025 is by no means uncommon. In the instance of strippings of the latter gravity, I found the percentage of solids to be 18·74.

Now, if all we knew concerning a sample of milk was that its gravity was 1·025, we might with equal reasonableness conclude, either that it contained fifteen or twenty per cent. of extraneous water, or that it was surcharged with cream.

If, by adding fat to milk, the specific gravity is lowered, it follows that by subtracting fat (*i.e.*, by skimming) the specific gravity is raised; and hence the explanation of the reaching of the high M. mark by skimming.

A certain trick of the milk trade is fostered by the employment of the lactometer. The milk is partially denuded of cream (accomplished conveniently by adding a certain quantity of skimmed milk to the fresh milk), and thereby raised in gravity. That being accomplished, it is dosed with water, and its gravity is thereby lowered to the normal standard.

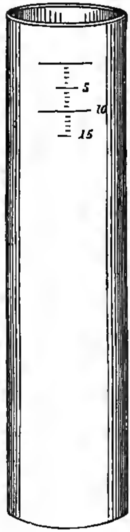
Let no one think that he would discover such a trick by making an estimation of cream; for watered milk throws up its fat in the form of cream more perfectly than unwatered milk.

Another objection relative to the lactometer (which, however, pertains to the application of the hydrometer to organic fluids generally) is drawn from the circumstance that a comparatively small change in density corresponds to a great change in composition. Making total abstraction of the difficulty and uncertainty dependent on the cream, and regarding milk as a solution of caseine and milk-sugar, it will be seen that whereas the specific gravity of water rises only from 1·000 to 1·032 in passing into milk, the water receives 9·2 per cent. of milk solids. In other words, whilst the density goes up only three per cent., the solids go up nine per cent. It is, therefore, disadvantageous to estimate rise in solid content by rise in density. Mineral substances, when they dissolve in water, raise the density far more rapidly than organic substances. The contrast in this respect is very well shown when chloride of potassium is compared with milk-solids. Thus a ten per cent. solution of chloride of potassium has a specific gravity of 1·065 at 15° Cent., whereas a ten per cent. solution of caseine and milk-sugar has a specific gravity of about 1·035.

To be of any value at all, a specific gravity determination in the case of such a fluid as milk must be taken with extreme accuracy; and, as is well known, the taking of specific gravities with great accuracy is not by any means one of the most facile of operations, and is certainly not easier than the taking of solid residues directly.

From a careful consideration of the whole subject, I am convinced that one of the most necessary steps to be taken in milk-analysis is to abandon the use of the lactometer.

The creamometer is a graduated tube, in which milk is allowed to stand and throw up cream, the volume of which is afterwards to be read.



It is, of course, unnecessary for the graduation to be continued throughout the whole extent of the tube. If the graduation be prolonged only for the uppermost fifteen per cent., that will be amply sufficient for all practical purposes—*vide* fig.

Normal milk yields about ten per cent. of cream; but that is subject to great irregularity, and a milk may yield very much less without having been tampered with, or it may yield the ten per cent., and, nevertheless, have been tampered with. As will be explained in the chapter devoted to cream, that fluid is subject to great variations in richness. The creamometer is at best a treacherous guide.

In addition to the lactometer and the creamometer, there is likewise an instrument, the indications of which depend upon the degree of opacity produced by the fat globules. It is an instrument which I have never tried, and which, indeed, does not promise much.

The only really safe and satisfactory manner of examining milk is by means of an analysis of it. This used to be considered a long and tedious, and little satisfactory operation. By the aid of a few simple devices, milk-analysis may be very much simplified. The first step to be taken is to determine the milk-solids, and, of course, the water, which is the difference between the solids and the quantity of milk which yields them. The detail of this operation will be given in next chapter. After having determined the milk-solids, the fat is next to be determined. If the amount of fat be subtracted from the amount of milk-solids, the amount of "solids not fat" will be arrived at. A knowledge of this datum is (as will be explained) sufficient to enable a judgment to be come to as to whether or not the sample of milk had been watered.

As a rule, an examination of milk, which has proceeded thus far, is complete. If only watering or skimming, or both, had taken place, the examination would have been ample.

The determinations of caseine and of milk-sugar are useful when the question arises of other possible adulteration. The determination of ash is made with a view of ascertaining the presence of extraneous mineral matter. It has the merit of being very easy of execution. A highly-watered milk will obviously, as one of its characters, show too low an ash. In the following chapters we shall describe in detail the method of arriving at each of these data.

CHAPTER III.

MILK-SOLIDS.

The first step in dealing with a sample of milk is to ensure that it is thoroughly mixed up. This is most conveniently done by pouring it from one vessel to another; and it is essential to attend to this particular in order to avoid getting either too much or too little cream—that is to say, either a greater or less proportion than the sample really contains. It is also well, in this preliminary stage of the inquiry, to make out whether the milk be sour or not, and whether or not it be curdled. If very sour, there is of course a chance of destruction of some of the organic material, and the degree of acidity in such a case ought to be measured by means of standard solution of alkali. If the milk be curdled, care will also have to be taken to avoid an unequal distribution of the caseine; and in cases of this kind, I do not like to use the pipette for measuring off the quantity of milk, but I prefer to weigh out the quantity of milk taken for analysis.

Assuming that the milk is fresh and in good condition, it may be measured in a small pipette—*vide* fig.

The quantity taken for analysis is five cubic centimeters. Pipettes for the discharge of 5 c. c. may be purchased of

Messrs. Townson & Mercer, who supply them graduated very satisfactorily. The pipette should be accurate, within $\frac{2}{100}$ of a cubic centimeter; and should be tested by being charged with water, and discharged into a counterpoised beaker or flask, which, with its contents, is to be weighed. The discharged water should not differ from five grammes by more than 0·02 grammes.

In order to be able to take milk-solids, the experimenter requires—

1. A balance.
2. Small platinum dishes.
3. Water bath.
4. Pipette.

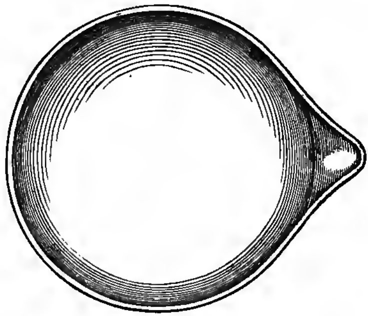
If a good chemical balance and weights be at hand, so much the better. If not, and the question arise relative to the least practicable expenditure in the matter of balance, the following information may possibly be acceptable.

I have seen a balance made by Becker & Sons, of New York, and Kruiskadv, Rotterdam,* which indicates two milligrammes quite distinctly when loaded with fifty grammes, and which costs £2. This balance, which is No. 14 on Messrs. Becker & Sons' published catalogue, will answer very well. For weights, it is essential to have a good set, and the box costing 30s. will be required.

If 5 c. c. of milk be taken, it will be obvious that an error of five milligrammes equals 0·1 gramme per 100 c. c.; and with a balance and weights and pipette, such as just mentioned, there should be no difficulty in getting determinations of residue which are not more than a few hundredths per cent.

* Mr. Henry Gillman, 143 Brecknock Road, London, N., is sole agent in England.

off the truth. The evaporation to dryness is most conveniently performed in a small platinum dish weighing some twelve grammes, and of the size figured.



If there be many milks to examine, it will be well to have a set of the little dishes (which cost 14s. a piece, and which are numbered on the lip). The dishes are to be cleaned and weighed, and the weights noted down: they will alter in weight only very slowly, and even if in active use, require reweighing only every now and then.

The dishes are conveniently heated in an oblong copper bath, with round holes cut in the top to receive them. The bath should be some six inches deep, and is charged with water. It is conveniently supported on a tripod, and heated with a Bunsen burner.

The dishes having been weighed, placed in order in the bath, and each one having received its charge of 5 c. c. of milk, the water in the bath is to be made to boil vigorously, and maintained boiling for three hours. At the expiration of that period the 5 c. c. of milk in each dish will have completely dried up. Each dish, with its contents, is removed from the bath, its outside is wiped, and itself and contents forthwith weighed.

The weight of the dish subtracted from the weight of conjoined dish and contents leaves the weight of the milk-solids given by the 5 c. c. of milk. By multiplying that weight by 20, the yield from 100 c. c. of milk is arrived at. If care be taken in this operation, results may be obtained which differ from one another by only a small figure in the second decimal place in percentage.

When I first worked this process, I employed a pipette which discharged not 5 c. c., but 5 grammes of milk, of average density; and in that way obtained results which, multiplied by 20, expressed percentage. I have, however, come to the conclusion, that it is better to express the result not exactly in percentage, but in grammes yielded by 100 c. c. of milk, and that mode of statement I am now in the habit of adopting.

As before said, if the milk be curdled, it is not well to use the pipette, and to take the 5 c. c., but to weigh out an irregular quantity of the milk (about 5 grammes), and dry it up.

The following examples will serve to illustrate the degree of accuracy easily attainable by this process.

A sample of good country milk was submitted to the process four times, with the following results:—

	MILK.	MILK-SOLIDS.
I.	4·969 grammes gave	0·616 grammes.
II.	5·0105 „ „	0·6255 „
III.	5·007 „ „	0·623 „
IV.	5·0145 „ „	0·626 „

Expressed in percentage, this is equivalent to—

MILK.	MILK-SOLIDS.
100 grammes gave . .	12·40 grammes.
" " " . .	12·48 "
" " " . .	12·44 "
" " " . .	12·48 "
and the mean . .	12·45 "

A specimen of rich town-fed milk yielded in four experiments—

	MILK.			MILK-SOLIDS.
I.	5·000	grammes	gave	0·7035 grammes.
II.	5·004	"	"	0·705 "
III.	5·000	"	"	0·7025 "
IV.	5·006	"	"	0·705 "

Or in percentage—

MILK.	MILK-SOLIDS.
100 grammes gave . .	14·07 grammes.
" " " . .	14·09 "
" " " . .	14·05 "
" " " . .	14·08 "
and the mean . .	14·07 "

These are not exceptionally carefully done, and only illustrate the degree of accuracy which is attainable by the most ordinary care.

In conclusion, it remains to add, that such results are not to be expected if the residues be weighed before the expiration of the prescribed time—viz., the three hours—and that the water in the bath must be kept boiling vigorously the whole time. By prolonging the drying for a second period of three hours, no sensible diminution takes place in the milk-solids.

The employment of plaster of Paris or sand (both of which have been recommended for the purpose of rendering milk residues porous) is to be avoided. When only five cubic centimeters of milk are taken, as has been recommended in this chapter, it is likewise unnecessary to stir up the milk during the evaporation and drying.

Since writing the first edition of this book I have had abundant opportunity of judging of the suitableness of the system of milk-analysis for the requirements of the Public Analysts. The system has fully answered my expectations. By prescribing a fixed quantity of milk, a fixed temperature, and a fixed period of drying, *i.e.*, a full three hours, and by abstaining from the delusive recommendation, "dry till the weight is constant," I have discouraged the cooking of results. At the same time the accuracy of the work, when the instructions are followed, has become matter of common knowledge.

CHAPTER IV.

THE FAT.

The fat in milk is estimated by dissolving it in ether (which dissolves it, but does not dissolve any other constituent of milk), and evaporating the ethereal solution to dryness, and weighing the dried residue. It is not practicable to apply the ether directly to the milk itself, but the ether must be applied to the dry milk-solids.

The residue obtained, as described in last chapter, by evaporating and drying up 5 c. c. of milk, may be taken for the determination of the fat.

This residue, as will be understood, is contained in a small platinum dish. Ether is to be poured into the dish, and heated to the boiling-point, and poured out through a small filter. This operation of boiling and pouring off the ethereal solution must be repeated at least three times, and care is required to let none of the fat make its escape over the bottom of the dish. The filter should be large enough to avoid the chance of spilling the ethereal solution as it is being poured on to the filter. It is advisable to wash the bottom of the little platinum dish with ether, in order to avoid all chance of loss. Attention must also be paid to the filter-paper after the ether has passed through it. Of course it will require washing with ether; and after the residual ether has evaporated off, will be found with a little rim of fat surmounting it. This is best dealt with by cutting it off, and macerating it with a fresh portion of ether, which may then be rapidly poured through a second small filter. In order to facilitate the solution of the fat, the milk residue may be first moistened with alcohol, which will tend to disintegrate it, and favour the action of the ether upon it.

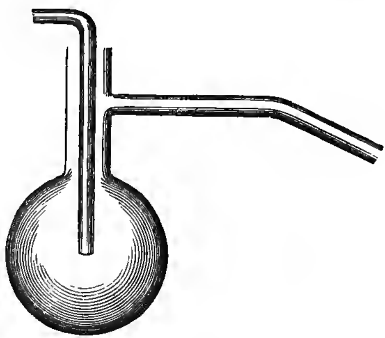
With regard to the quality of the ether employed, it should be tolerably dry; but it may be methylated ether. Of course it should leave no appreciable residue when 50 c. c. of it are evaporated and dried in the water-bath. The cost of such ether is about 16s. per gallon, and the cost of the ether consumed in each determination of fat is not more than two-pence. I would, however, give the advice to be liberal with the ether; for it is false economy to ruin the determination for the sake of saving ether.

As will be apparent on trying practically to make these determinations of fat, the yield from 5 c. c. of milk is rather inconveniently small. I prefer to take 10 c. c. of milk, and to evaporate down in a larger platinum dish. A dish capable of holding 40 c. c., which costs about 30s., will answer very well. A small platinum spatula may be inserted into the milk, and used to stir it up occasionally during the evaporation. In this instance, it is unnecessary to push the drying of the milk-solids to completeness, and an hour's evaporation in the water-bath is amply sufficient for the purpose. Just at last, the milk residue should be moistened with alcohol to soften it. The mode of dissolving out the fat with ether, and the passing of the ethereal solution through the filter, and the subsequent treatment of the residual rim of fat in the filter-paper, has been already explained.

The ethereal solution of fat having been obtained (and, by the way, it ought never to be less than 50 c. c.), the next point to be attended to is the evaporation of the ether, and the getting of the residue of fat.

In laboratories where there is a platinum dish capable of holding 100 c. c., such as is used in taking water residues, that may be employed for the purpose of containing the solution.

The dish, having been weighed, is charged with the ethereal solution, and placed in warm water, whereupon the evaporation of the ether may be made to proceed gently. As the evaporation approaches its termination, a change will be visible in the aspect of the solution. It will become turbid, owing to the trace of water and small quantity of alcohol,



which gradually predominate over the ether, being incapable of dissolving the fat. When this stage is reached, the dish should be transferred to the water-bath, and heated to 100° C. After being maintained at 100° C. for a short time, the solution will again become clear, owing to the evaporation of the trace of water and alcohol. When this clearness has come on, the fat is dry, and the dish may be removed from the bath, wiped, cooled, and, along with its contents, weighed. The weight of the empty dish being subtracted, the difference is the weight of the fat yielded by the milk. This multiplied by 10 or 20, as the case may be, gives the number of grammes of fat yielded by 100 c. c. of milk.

If it be desired to recover the ether, the evaporation may be managed in a small retort—*vide* fig.

In such a case, the empty retort should be first weighed, and subsequently the retort charged with the dry fat is to be weighed. It will further be necessary to send a stream of dry air through the retort towards the end of the operation.

I do not, however, think that a saving of two or three pence—the value of the ether—is a sufficient inducement to cause the analyst to complicate his apparatus. The avoidance of disengagement of ether vapour into the laboratory may, however, under some circumstances, be a reason for adopting an arrangement of this description.

In general, a milk-analysis is complete when milk-solids and fat have been taken. If the latter be subtracted from the former, a very important datum—viz., *milk-solids not fat*—is arrived at. This datum, which is the most constant quantity in milk-analysis, gives, by a very simple calculation, the extent of watering to which the milk has been subjected.

CHAPTER V.

CASEINE.

UNDER the title of caseine—perhaps it would be better to say crude caseine—I mean to designate the entire nitrogenous material of milk.

After the dry milk-solids have been got, and after the fat has been washed out of them by means of ether, as was explained at length in the last chapter, there remain behind the caseine the milk-sugar and the ash. By extracting with strong alcohol, and ultimately adding a little boiling water, so as in effect to extract with very weak hot alcohol, the milk-sugar and the soluble part of the ash, *i.e.*, the chlorides, will pass into solution. The caseine which remains behind is washed off the filter-paper into a little platinum dish, and dried up in the water-bath till it ceases to lose weight. It is weighed along with the containing vessel, and then ignited, and the weight of the vessel and adherent ash (phosphate of lime) subtracted from it. As has been already remarked, the phosphate of lime exists really in a state of chemical combination with the caseine in milk. The quantity of milk recommended for the estimation of fat, viz., 10 grammes, is suitable for the determination of the caseine. Of course, if the product of the operation be multiplied by 10, the quantity of caseine yielded by 100 c. c. of milk will be arrived at.

Another method of procedure, which is very generally recommended, but which I do not like so well as that just described, consists in taking a considerable quantity of milk —say 50 or 100 c. c. of milk—and, without any preliminary evaporation to dryness, precipitating the caseine, which is to be washed with water, alcohol, and ether, and then to be dried and weighed. The precipitation is effected by warming the milk, and acidulating it with almost any common acid: either hydrochloric or sulphuric, or even acetic acid will do. As aforesaid, I do not like that modification so well as the one first given.

A very different method of determining caseine in milk consists in measuring it by the albuminoid ammonia which it is capable of furnishing. This is certainly the quickest process, and is very satisfactory.

In order to practise it, the milk must first be diluted with a known volume of water, so that one volume of dilute milk may contain accurately $\frac{1}{100}$ of a volume of milk. This is conveniently accomplished by measuring out with the pipette 10 c. c. of milk, and dropping it into the litre flask, which is subsequently filled up to the litre mark. Or, of course, 5 c. c. of milk may be diluted to 500 c. c.

It is not necessary to use distilled water for the purpose, inasmuch as the error introduced by ordinary river or town water is inappreciable. The quantity of the diluted milk which is required for experiment is 5 or 10 cubic centimeters, equivalent to $\frac{5}{100}$ or $\frac{10}{100}$ of a cubic centimeter of real milk.

The mode of operation is as follows:—

Ten grammes of solid potash and 0·4 gramme of crystals of permanganate of potash are boiled with about half a litre of water, the whole being contained by a retort provided with a tubulure, and connected with a Liebig's condenser. The liquid is allowed to distil, and successive portions of distillate tested for ammonia. So soon as water begins to distil over in a state of freedom from ammonia, the portion of diluted milk is to be introduced into the retort through the tubulure.

The distillates which subsequently come over are charged with the ammonia arising from the destruction of the caseine.

The ammonia is to be measured by means of the Nessler test, which is now very well known. The details of the measurement of ammonia will be understood by all persons who are in the habit of working the water process of Wanklyn, Chapman, and Smith, and it is unnecessary to enter into them here.

Every one part by weight of caseine gives, treated in this manner, 0·065 part of ammonia. The yield of "albuminoid ammonia" from 100 c. c. of genuine milk is 0·26 grammes.

It is only by persons who work the ammonia process of water-analysis, and only in laboratories where arrangements are made for that process, that the convenience of this determination of caseine will be appreciated.

CHAPTER VI.

MILK-SUGAR.

AFTER the milk-solids have been deprived of fat by means of ether, as explained in Chapter IV., they may be made to yield up the milk-sugar, if they be treated with alcohol and hot water. This has been explained in the preceding chapter.

It remains here to follow the weak alcoholic solution after its passage through the filter on which the caseine had been deposited. The solution is to be evaporated to dryness in the water-bath, and the residue adherent to the vessel in which the evaporation is performed is to be weighed along with its containing vessel.

That having been done, it is ignited gently, and the residue on ignition subtracted from the total weight before ignition. The difference is the yield of milk-sugar. Multiply this by 10, and the number of grammes of milk-sugar yielded by 100 cubic centimeters of milk is found. With some chemists, a titration of milk-sugar, by means of copper-solution, is in great favour. For this purpose 50 or 60 c. c. of milk are gently warmed, and mixed with a little acetic acid in order to precipitate the caseine, which is separated by means of a filter. The filtrate is used in the titration in the following manner:—It is first diluted with nine times its volume of water, so that one litre contains the milk-sugar of 100 c. c. of milk. A measured quantity of standard copper-solution is then placed in a white basin, and diluted with four times its volume of water, and heated to boiling. Into it, whilst boiling, is dropped the above-mentioned diluted milk, previously acidulated and filtered. As the dilute milk drops from a burette, it instantly reduces the boiling copper-solution, which deposits red oxide of copper. The dropping is to be continued until the boiling copper-solution ceases to be reduced—until it is exhausted. The point of exhaustion is determined *roughly* by observing when the blue colour leaves the solution, and *finely* by observing the exact point at which ferrocyanide of potassium ceases to strike a red colour with the filtered solution, which must be slightly acidulated with acetic acid before being tested with the ferrocyanide. The standard copper-solution is prepared by dissolving 34·65 grammes of crystals of sulphate of copper in 200 c. c. of water. To this solution is added a solution made by dissolving 173 grammes of double tartrate of potash and soda in 480 c. c. of caustic soda-solution, of specific gravity 1·14. The whole is diluted till it occupies the volume of one litre.

The standard solution, so prepared, is of such a strength that 10 c. c. are equivalent to 0·067 grammes of milk-sugar (dry at 100° C.)

I am not in the habit of using this process, but without doubt it is occasionally of value.

CHAPTER VII.

ASH.

If the milk-solids be ignited, the organic matter is destroyed, and the inorganic matter or ash remains behind. The operation is managed in a very simple manner. The small platinum dish containing the milk-solids from 5 c. c. of milk is placed on a small triangle, either of platinum, or of iron-wire, or of iron-wire covered with tobacco-pipe. The last mentioned is an admirable form of support, and is very well known to chemists. The flame, either of a spirit-lamp, or of a Bunsen burner, is then made to play upon the platinum dish. By-and-by the organic matter is burnt up, and a grey ash remains behind. The platinum dish and its contents are then allowed to cool, and weighed. After subtracting the weight of the dish, the weight of the ash remains. This, multiplied by 20, equals the number of grammes of ash or mineral matter contained by 100 c. c. of milk.

The importance of a determination of ash depends upon the fact that the correctness of it at once answers the question whether or not the milk has been adulterated with chalk, salt, or other inorganic impurity. I have made hundreds of determinations of ash, and not yet come across a single case of adulteration of this kind.

As will be seen on looking back, the quantity of ash contained by 100 c. c. of milk is between 0·7 and 0·8 grammes.

Now, suppose the milk to be watered—with, say London water. In such a case the ash would be diminished, inasmuch as 100 c. c. of London water contains only 0·03 grammes of mineral matter, whilst 100 c. c. of milk contains 0·73 grammes of mineral matter. Watering will, therefore, be indicated by diminished ash; and in cases of watering, it is worth while to make a careful determination of ash as a sort of confirmatory test.

CHAPTER VIII.

CALCULATION AND STATEMENT OF RESULTS.

THROUGHOUT the foregoing chapters, the mode of statement recommended has been to reckon the milk by measure in cubic centimeters, and the products—the milk-solids or fat, &c.—in grammes. This form of statement will be found to be the most convenient, involving, as it does, the least possible calculation.

Occasionally, however, as in the case of sour milk, we are compelled to weigh the milk instead of measuring it.

In such a case, a simple calculation will reduce the percentage statement into a statement in the prescribed form, *i.e.*, of how many grammes are yielded by 100 c. c. of milk. If the specific gravity of the sample of milk be known, the reduction consists in simply multiplying by the specific gravity; if the specific gravity be unknown, the milk should be assumed to be of average specific gravity, viz., 1·029, and the calculation made accordingly.

In milk-analysis there are two kinds of statement in use, viz., percentage statement—how much of any constituent of milk is contained by 100 parts of milk; and the other kind of statement, how many grammes of any constituent are contained by 100 cubic centimeters of milk. Inasmuch as 100 c. c. of average milk weighs 102·9 grammes, this second statement approximates to a statement of parts per 102·9 parts.

In the next chapter, which is a reprint from the *Chemical News*, the form of statement is percentage, and the various data would be reduced to the other measure by multiplication by 1·029.

Having cleared away any confusion arising from this slight difference in scale, we pass on to consider the practical use to be made of the various data afforded by milk-analysis.

As will be remembered, 100 c. c. of milk of average quality contains 12·81 grammes of milk-solids. Very rich—exceptionally rich—stall-fed milk contains 14·47 grammes of milk-solids. Now, it must be obvious to every one, that very rich milk, let down with a little water, will simulate milk of average quality.

There is a certain limit below which the milk of well-fed cows is never known to fall. Below 11·8 grammes of solids per 100 c. c., milk has not been known to fall.

The most variable constituent of milk is the fat; and if the quantity of fat be deducted from the milk-solids, the "*milk-solids not fat*," which is a very constant datum, is obtained. Taking the milk-solids in country milk, and deducting the fat from it, there remains 9·65, which is the "milk-solids not fat." Similarly, the "*milk-solids not fat*" in stall-fed milk amount to 10·35 grammes per 100 c. c.

The best way of dealing with the question of watering is to assume a perfectly rigid standard of normal milk, and to treat all departures from it as sophistications. Normal country milk is of such a strength, that 100 c. c. contains 9·65 grammes of caseine, milk-sugar, and ash together—that is to say, of *milk-solids not fat.*

In one cubic centimeter of normal milk there is therefore $\frac{9 \cdot 65}{100}$ grammes of *milk-solids not fat.*

In order to find how much genuine milk there is in 100 c. c. of a given sample of milk, the rule is, therefore, to divide the number of grammes of the *solids not fat* by 0·0965.

In the next chapter the subject is still further developed.

Another method of calculation is founded on the observation that skim-milk (normal country milk from which the fat has been removed) contains 10 grammes of "solids not fat" in 100 cubic centimeters. This will be obvious on looking at the analysis on page 1.

In 100 cubic centimeters of average milk there are 3·16 grammes of fat, or 3·5 cubic centimeters of fat. Subtracting from the 100 c. c., there remains 96·5 c. c. of skim-milk, containing 9·65 grammes of "solids not fat." Normal milk absolutely skimmed, therefore, contains 10 grammes of solids per 100 c. c. of milk.

That being understood, the calculation of watering may be made at sight.

The rule is this.

Having made the analysis of the milk, calculate the volume of the fat (assuming that 0·9 gramme equals 1·0 c. c. of fat), and subtract the volume of the fat from 100, and the difference is the number of c. c. of absolute skim-milk in 100 c. c. of the milk. Note, then, whether or not the ratio of "solids not fat" to the volume of absolute skim milk is 1 to 10. If this ratio be exactly 1 : 10 the milk is unwatered. If it be 0·80 to 10·00 the milk contained 80 parts of skim-milk to 20 parts of water. The unit of solids represents unwatered skim-milk: whatever the unit is deficient represents "added water."

CHAPTER IX.

THE MILK-SUPPLY OF THE LONDON WORKHOUSES.

HAVING had occasion to examine a large number of specimens of milk during the year 1871, I have made some observations on the subject, which possibly may not be deemed to be unworthy of the attention of those chemists who may have a like task before them.

The two common forms of malpractice which occur in the milk-trade are—the practice of removing the cream from the milk, and the practice of diluting the milk with water; and the testing of milk resolves itself into the detection of skimming and watering, and the measurement of the extent to which these operations have been carried.

The possibility of detecting whether or not a specimen of milk has undergone impoverishment depends obviously on the possibility of assigning a normal composition to milk, or, at any rate, on the possibility of fixing limits beyond which the composition of milk does not vary.

From the observations of Alexander Müller and Eisenstuck, who carried out an investigation for the Royal Agricultural Society of Sweden, it appears that the milk yielded by a herd of cows remains very constant in composition throughout the year. A daily analysis of the milk given by fifteen cows, of different breeds, but uniformly well fed, exhibited the percentage of solids in the milk as never once during the entire year having fallen so low as 11·5. The highest percentage of solids was 14·08. Only four times during the year did the solids fall below 12 per cent. The average was 12·8 per cent.

My own observations, made on an entirely different plan, fully bear out the statement that cows' milk does not fall so low as 11·5 per cent. of solids, and seldom so low as 12 per cent.

The following analyses may be published :—

Date.	Description.	Percentages.		
		Cream.	Solids dry at 100° C.	Ash.
I. 17th Feb. 1871 .	D. R.	10	12·24	0·76
II. 18th Feb. 1871 .	D. R.	...	12·04	0·68
III. 21st Feb. 1871 .	Cambridgeshire	16	12·28	...
IV. " " . .	Surrey . . .	11	12·22	...
V. " " . .	Herts	11	13·08	...
VI. " " . .	Essex	11	11·80	...
VII. " " . .	Essex	...	14·34	...
VIII. March 1871 . .	Country milk .	9·8	12·45	0·71
IX. " " . .	Town-fed milk .	13·0	14·07	0·74
X. April 1871 . .	Alderney milk .	11·5	12·65	0·70

The first two specimens, named D. R., were specimens of milk bought from milk-dealers believed to be perfectly honest. The next five specimens were samples of milk produced on farms in the different counties named in the table. Specimen VIII. is a sample taken by myself, out of some fifty or sixty gallons of milk fresh from the country. Taken altogether, the ten analyses represent the composition of an immense quantity and of a great variety of milk, and support the conclusion arrived at in Sweden by Müller and Eisenstuck.

Before leaving the subject of the normal composition of milk, it is right to refer to the laborious investigation by Goppelsröder (*vide* "Verhandlungen der Naturforschenden Gessellschaft in Basel," 1866), which, at first sight, would seem to be in opposition to the above.

In reference to Goppelsröder's paper, the remark should first be made that that chemist does not appear to deny that the solid residue in the milk of a herd of cows keeps constantly above the level just indicated. The point which he insists upon is, that the milk of a single cow sometimes falls in richness below the normal level, and observations are cited in support of this statement. An examination of the results given in his paper does not lead me to a similar conclusion. In his paper I find many determinations of the solids in milk believed to be unsophisticated. Only four out of the entire number fall below 12 per cent. Now it is obvious that, however constant milk may happen to be as a matter of fact, it must always be possible, by a sufficient multiplication of analyses, to exhibit an analysis showing the sample of milk as having a composition outside the normal limit of variation. In other words, there is such a thing as error of experiment, and the question to be asked respecting Goppelsröder's four isolated cases of milk showing less than 12 per cent. of solids is, whether this divergence from the standard composition is real, or only an error of observation. Two of these instances occur in Table I., at the beginning of the paper. Among eighteen samples of milk, yielded by a single cow in eighteen consecutive days, he finds one sample yielding 10·69 per cent. of solids, and another yielding 11·41 per cent. In the same table Goppelsröder records the percentage of cream, and the specific gravity of the milk before and after skimming. It is remarkable that the two low percentages of solids are not accompanied by low yields of cream or low specific gravities. The former of the two (viz., the 10·69 per cent. of solids) is accompanied by 10 per cent. of cream, sp. gr. 1·0316 before skimming, and sp. gr. 1·0332 after skimming; the latter (viz., the 11·41 per cent. of solids) by 11·2 per cent. of cream, sp. gr. 1·032 before and sp. gr. 1·034 after skimming. The third instance of a too low solid contents is to be met with in Table III., being the evening milk given by the last of eight cows. Percentage of solids, 11·43; cream, 7·5 per cent.; sp. gr. before skimming, 1·0315; sp. gr. after skimming, 1·0335. In this instance the cream is indeed rather low, but then the effect of skimming on the specific gravity of the milk is considerable, and the specific gravity is high.

It is perfectly true that if a little cream be removed from rich milk, and a little water (I believe it should be warm) be added to the milk, the creamometer and "lactodensimeter" may be cheated, so that there shall be want of correspondence between the indications of these instruments and the solids in the milk. But in the examples at present under discussion we are not dealing with skilfully sophisticated milk, but with milk in the natural condition as given by the cow. If the figures in the tables be correct, the cow must have, in these three instances, given milk not only abnormally poor in solids, but also in an abnormal physical condition, as if it had been manipulated by the fraudulent milk-dealer.

The fourth case of abnormally low solids occurs in Table IV., being the milk of the third cow, which is recorded as containing 9·54 per cent. of solids. In this instance, unfortunately, the yield of cream is not given. The sp. gr. before skimming was 1·0279, but the sp. gr. after skimming is not given. I observe, moreover, that the next solid contents of the table is a misprint, viz., 3·7677 instead of 13·7677 (that it is a misprint is shown by the numbers for the ash, and the number given as the ratio of the ash to the total solids).

I do not consider that Goppelsröder's four exceptional cases are sufficiently well established; and I consider it to be a well-established fact that the milk of a herd of cows in good condition always contains more than 11·5 per cent. of solids, and that single cows almost invariably (if not always) yield milk containing more than 11·5 per cent. of solids.

In dealing with milk-supply on the large scale, we are little concerned with the possibility of single animals giving abnormal milk, and need only concern ourselves with milk of normal quality, all departures from the standard being looked upon as sophistications.

The following, which is the result of several concordant analyses of country-fed milk, may be taken as representing normal milk. In 100 grms. of milk—

Solids (dry at 100° C.) . .	12·5 grms.
Water	87·5 ,,
	100·0

The 12·5 grms. consist of 9·3 grms. of "solids which are not fat," and of 3·2 grms. of fat.

If we consider the changes in composition which the addition of water to milk will produce, it will be apparent that it must diminish the proportion of solids in the milk, whilst the effect of skimming is to diminish the proportion of fat, and to leave the proportion of "solids not fat" unaltered (or indeed, strictly speaking, to make a very trifling increase in the proportion of the "solids not fat").

Treating the question quite rigidly, which I believe is the proper way of dealing with it, we arrive at the following :—

Problem I.—Given the percentage of "solids not fat" ($=a$), in a specimen of sophisticated milk (*i.e.*, milk either watered or skimmed, or both),—required the number of grammes of genuine milk which was employed to form 100 grms. of it.

Answer.—Multiply the percentage of "solids not fat" by 100, and divide by 9·3. Or—

$$\frac{100}{9 \cdot 3} a$$

Problem II.—Given the percentage of "solids not fat" ($=a$), also the percentage of fat ($=b$), in a specimen of sophisticated milk,—required the number of grammes of fat which have been removed by skimming from the genuine milk which was employed to form 100 grms. of it.

Answer.—

$$\frac{3 \cdot 2}{9 \cdot 3} a - b$$

In translating fat into cream, the rule is that a removal of 0·2 grm. of fat equals a removal of 1·0 grm. of cream. This rule is directly founded on experiment. I do not, however, claim a high degree of accuracy for the measurement of the cream.

Finally, a slight refinement may be noticed. If a specimen of sophisticated milk has been produced by both skimming and watering, it will be obvious, on consideration, that the extraneous water employed in manufacturing 100 grms. of it is equal to the difference between 100 and the quantity of genuine milk employed to make 100 grms. of sophisticated milk, together with a quantity of water equal to the fat removed by skimming.

$$\text{Extraneous water} = 100 - \frac{100}{9{\cdot}3}\,a + \frac{3{\cdot}2}{9{\cdot}3}\,a - b$$

$$= 100 - \frac{100 - 3{\cdot}2}{9{\cdot}3}\,a - b$$

An investigation of the different milks supplied to the different London Unions (which was made by me for the Government, at Mr. Rowsell's instance, last year, and which is published in Mr. Rowsell's "Report on the System of Supply of Provisions for the Workhouses of the Metropolis") will furnish an illustration of this method of interpreting the results of milk-analysis.

A sample of milk was procured from each workhouse by Mr. Rowsell at two different dates, and forwarded to me for analysis. The analysis of the earlier sample is marked I. in the following table, and that of the later sample is marked II. Samples were also forwarded to Dr. Letheby, who arrived at the same general results as myself; but either from his having slightly different specimens, or from employing different methods of analysis, his numbers sometimes exhibited some considerable departures from my own. There was, however, no difference in the practical effect of the two reports.

On inspecting the table, it will be seen the milk from twenty-eight Unions is reported upon. A well-known metropolitan Union is conspicuous by its absence, and the report would not be complete unless it were recorded that the Westminster Union refused to furnish Mr. Rowsell with information and samples.

Out of the fifty-six samples of milk only fifteen were unwatered, or nearly unwatered. Nine of these fifteen were skimmed, leaving only six that were at once unwatered and unskimmed. Accordingly, about 10 per cent. of the milk supplied to London workhouses appears to be genuine. In the years 1871 and 1872 I examined about a thousand samples of milk bought in London for the *Milk Journal*, and arrived at a similar conclusion as to the general condition of the milk-trade in the metropolis (*vide* the Supplement to "Watts's Dictionary of Chemistry," article Milk-Analysis, p. 830).

It is curious to compare the language of the contract under which (as appears from Mr. Rowsell's report) the dealer supplied the various Unions with milk with the quality of the article as exhibited by the analysis. "New unskimmed milk, unadulterated;" "Genuine as from the cow;" "Best new unskimmed milk, to produce 10 per cent. of cream," occur in the contracts.

The Fulham Union is distinguished from the rest by having a contract for "skim-milk," the terms of the contract being "genuine, unadulterated milk, *pure skim*," and the Fulham Union gets an excellent quality of skimmed milk. Stepney has the most magniloquent contract, and is the worst supplied with milk.

In 100 Grammes of Sample of Milk.				Calculated.			
		Grms. of Solids not Fat.	Grms. Fat.	Grms. of Genuine Milk.	Grms. of Fat Removed.	Grms. of Cream Removed.	Grms. of Extra Water.
		$a.$	$b.$	$\frac{100}{9\cdot3}a.$	$\frac{3\cdot2}{9\cdot3}a-b.$		$100-\frac{100}{9\cdot3}a+\frac{3\cdot2}{9\cdot3}a-b.$
Bethnal Green (St. Matthew)	I.	9·04	1·22	97·2	1·89	9·45	4·7
" " "	II.	4·38	2·08	47·1	-0·57	-2·85	52·3
Camberwell (St. Giles)	I.	8·37	1·14	90·0	1·74	8·70	11·7
" "	II.	8·94	0·96	96·1	2·12	10·60	6·0
Chelsea (St. Luke)	I.	9·36	2·24	100·6	0·98	4·90	0·4
" "	II.	7·48	2·86	80·4	-0·28	-1·40	19 3
Fulham Union	I.	9·09	1·52	97·8	1·61	8·05	3·8
" "	II.	9·30	1·80	100·1	1·40	7·00	1·4
St. George's Union	I.	9·52	2·44	102·6	0·84	4·20	-1 8
" "	II.	9·08	2·82	97·6	0·31	1·55	2·7
St. George-in-the-East	I.	6·55	2·32	70·5	-0·06	- 0·30	29·5
" "	II.	5·92	1·30	63·7	0·74	3·70	37·0
St. Giles-in-the-Fields and St. George, Bloomsbury	I.	9·13	1·50	98·2	1·65	8·25	3·4
" "	II.	7·17	1·96	77·1	0·51	2·55	23·4
Greenwich Union	I.	6·60	2·32	71·0	-0·05	-0·25	29·0
" "	II.	6·38	1·98	68·6	0·21	1·05	31·6
Hackney Union	I.	9·09	3·50	97·8	-0·47	-2·35	1·7
" "	II.	7·40	2·54	79·6	0·00	0·00	20·4
Hampstead (St. John)...	I.	8·44	1·50	90·7	1·40	7·00	10·7
" "	II.	7·74	3·00	83·3	-0·34	-1·70	16·4
Holborn Union	I.	8·27	1·84	89·0	1·01	5·05	12·0
" "	II.	7·64	2·40	82·1	0·23	1·15	18·1

Islington (St. Mary)	I.	7·70	0.92	82·8	1·73	8·65	18·9
" "	II.	7·06	1·45	75·9	0·98	4·90	25·1
Kensington (St. Mary Abbot)	I.	8·04	0·60	86·5	2·17	10·85	16·2
" " "	II.	6·08	1·26	65·4	0·83	4·15	35·4
Lambeth (St. Mary)	I.	6·54	1·56	70·4	0·69	3·45	30·3
" "	II.	7·08	1·22	76·1	1·22	6·10	25·1
Lewisham Union	I.	6·42	0·96	58·3	0·90	4·50	42·6
" "	II.	5·95	1·30	64·0	0·75	3·75	36·7
London (City of) Union	I.	8·84	2·82	95·1	0·22	1·10	5·1
" "	II.	6·26	1·10	67·3	1·05	5·25	34·0
St. Marylebone	I.	7·84	1·14	84·3	1·56	7·80	17·3
"	II.	9·44	3·06	101·5	0·19	0·95	–1·3
Mile-End Old Town	I.	9·55	1·96	102·7	1·32	6·60	–1·4
" "	II.	8·70	1·80	93·6	1·19	5·95	7·6
St. Olave's Union	I.	7·17	1·86	77·1	0·61	3·05	23·5
" "	II.	7·70	1·86	82·8	0·79	3·95	18·0
Paddington "	I.	7·22	1·44	77·7	1·04	5·20	23·3
"	II.	6·06	2·16	65·2	–0·07	–0·35	34·7
St. Pancras	I.	7·22	1·12	77·7	1·37	6·85	23·7
"	II.	4·94	1·64	53·1	0·09	0·45	47·0
Poplar Union	I.	7·40	0·76	79·6	1·79	8·95	22·2
" "	II.	5·96	0·90	64·1	1·06	5·30	37·0
St. Saviour's Union	I.	6·65	2·10	71·5	0·19	0·95	28·7
" "	II.	6·30	1·90	67·7	0·27	1·35	32·6
Shoreditch (St. Leonard)	I.	9·99	1·48	107·4	1·96	9·80	–5·4
" "	II.	9·44	2·36	101·5	0·89	4·45	–0·6
Stepney	I.	4·98	0·78	53·6	0·93	4·65	47·3
"	II.	5·09	0·58	54·7	1·17	5·85	46·5
Strand Union	I.	9·56	1·64	102·8	1·65	8·25	–1·2
" "	II.	9·16	2·46	98·5	0·69	3·45	2·2
Wandsworth and Clapham Union	I.	8·78	1·50	94·5	1·52	7·60	7·0
" " "	II.	8·66	2·86	93·1	0·12	0·60	7·0
Whitechapel Union	I.	5·62	0·68	60·4	0·25	1·25	39·8
" "	II.	6·06	1·90	65·2	0·19	0·95	35·0

In Column 1 is given the designation of the sample, viz., the name of the Union which furnished it, and the number of the sample.

In Column 2 is given the number of grms. of "solids not fat" contained by 100 grms. of the sample.

In Column 3, the fat.

In Column 4, the number of grms. of genuine milk which was employed in making the 100 grms. of sample (calculated).

In Column 5, the number of grms. of fat removed by skimming from 100 grms. of sample (calculated).

In Column 6, the number of grms. of cream which had been skimmed off 100 grms. of sample (calculated).

In Column 7 is given the number of grms. of extra water which had been put into 100 grms. of sample (calculated).

Inasmuch as I have submitted the analyses of these workhouse milks to severe and elaborate treatment, it is right that some particulars should be recorded concerning the manner in which they were conducted. The ash of each milk was determined, and in no instance was it excessive in amount, showing that no mineral had been used to adulterate the milk. For organic adulteration I made no elaborate analysis; but no indication of such adulteration presented itself in the course of the examination; furthermore, I should add that I have never yet met with a case of adulteration of milk with organic substances, and believe it to be of very rare occurrence.

The solid residue dry at 100° C. was taken with great—and I believe unprecedented—accuracy. I have made a study of the taking of milk-residues, and set down the average experimental error in the solid residue as not more than 0·02 per cent. The solid residues were taken twice over, and the mean of the two closely agreeing determinations was employed in the construction of the table.

The fats were taken with great care, but they do not pretend to so high a degree of accuracy as the total solids. It is hardly necessary to add that the numbers (designated as a) in the column headed "Grms. of Solids not Fat" were obtained by subtracting the quantity of fat ($=b$) from the quantity of total solids dry at 100° C.

The calculation of the quantities of genuine milk employed in making 100 grms. of the samples is based on the assumption, which I believe to be warranted, that milk is tolerably uniform in strength, consisting of 9·3 parts "solids not fat," 3·2 parts of fat, and 87·5 parts of water. This is the composition of country-fed milk. There is, however, an exceptionally rich milk given by highly stall-fed cows in town. This milk contains 10·0 parts of "solids not fat," 4·0 parts of fat, and 86·0 per cent. of water; but it is comparatively rare.

If, in any instances in the above table, this rich stall-fed town milk has been employed instead of average country milk, then the real amount of watering and skimming in those instances is a little higher than the table exhibits. In the table there are seven examples of more than 100 grms. of genuine milk being used in making 100 grms. of the sample. Of these, one appears to be an example of this town-fed milk, the rest not being sufficiently above 100 to call for such a supposition. The example to which I refer is the Shoreditch milk, which on the first occasion yielded 9·99 per cent. of "solids not fat," which is a very close approximation to the "solids not fat" in 100 parts of town-fed milk.

When a exceeds 9·3 a minus-quantity will correspond to it in Column 7, unless the slight correction for fat obliterate the minus-quantity of water. On calculating for town-fed instead of for country-fed milk, the minus-quantities in Column 7 will disappear in every instance. The calculation for town-fed milk instead of for country-fed milk, as in the table, is simple, viz., substitute 10 a for $\frac{100}{9 \cdot 3} a$; substitute 0·4 a for $\frac{3 \cdot 2}{9 \cdot 3} a$.

The occurrence of minus-quantities in the column headed "Fat Removed" requires a word of explanation. These minus-quantities have a real and substantial meaning. They are the quantities of fat which have been the reverse of removed—that is to say, which have been added to the milk. Whenever one of these minus-quantities occurs in the "Fat Removed" column, one of three things has happened:—Either the minus-quantity is within the limits of experimental error, as is the case with three of them (viz., − 0·06, − 0·05, and − 0·07), or the milk was town milk, or the milk had through imperfect mixing received an undue share of the cream. There are only four cases of the kind in the table, viz., − 0·57, − 0·28, − 0·47, and − 0·34.

CHAPTER X.

CREAM.

When milk is left at rest for a number of hours, it throws up a whitish layer well known as cream, which is simply milk very rich in fat.

In making examinations of cream, one of the first points which strikes the attention is the great variation in richness which it presents.

The percentages of water in different samples of cream I have found to be as follows:—

Sample	I.	72·20	per cent.	of water.
„	II.	71·20	„	„
„	III.	66·36	„	„
„	IV.	60·17	„	„
„	V.	53·62	„	„
„	VI.	50·0	„	„

And the history and complete analysis of each specimen is as follows:—

Sample I. Was raised by myself from an excellent specimen of country milk. It contained in 100 parts by weight—

Water	72·20
Fat	19·00
Caseine, milk-sugar, and ash . .	8·80
	100·00

SAMPLE II. Raised by myself from rich town milk.

In 100 parts by weight—

Water	71·2
Fat	14·1
Caseine, &c.	14·7
	100·0

SAMPLE III. The same cream as Sample II. It had been allowed to stand for twenty-four hours longer.

In 100 parts by weight—

Water	66·36
Fat	18·87
Caseine, &c.	14·77
	100·00

SAMPLE IV. Obtained from a well-known dairy. It had been allowed to rise for only five and a quarter hours.

In 100 parts by weight—

Water	60·17
Fat	33·02
Milk-sugar, caseine, and ash	6·81
	100·00

SAMPLE V. From the same dairy, but had had longer time to rise.

In 100 parts by weight—

Water	53·62
Fat	38·17
Caseine, milk-sugar, and ash	8·21
	100·00

SAMPLE VI. From another dairy, a very thick cream.

In 100 parts by weight—

Water	50·00
Fat	43·90
Caseine and milk-sugar . . .	5·63
Ash	0·47
	100·00

Every one of these creams is genuine and unsophisticated. It is instructive to compare the percentages of fat in the different creams.

Cream I.	19·00	fat	per cent.
,, II.	14·1	,,	,,
,, III.	18·87	,,	,,
,, IV.	33·02	,,	,,
,, V.	38·17	,,	,,
,, VI.	43·9	,,	,,

If we regard the determination of fat in Cream II. as questionable (for a reason to be presently explained), and if we accept the determination of fat in Cream I., to which the objection does not apply, and if we also accept the high yields of fat to which no objection can be raised, we are led to the conclusion that cream is sometimes twice as rich in fat as it is at other times. And that being granted, what becomes of the creamometer, regarded as an instrument of precision?

The rise of the cream is a physical phenomenon, depending on the difference in density between the globules of fat and the liquid in which they were floating, and also on the size of the globules. The difference between the cream and the skim-milk which has thrown it up is, that the former is milk highly charged with fat globules, and the latter is milk comparatively slightly charged with fat globules.

Cream is, in fact, a solution of caseine, milk-sugar, and milk-ash in water, holding in suspension much fat.

Skim-milk is a solution of the same ingredients which holds only little fat in suspension.

If this hold strictly true, it follows as a necessary consequence that the ratio of the water to the sum of the milk-sugar, caseine, and ash in the milk must be preserved in the cream.

In the instance of Cream I. we have an opportunity of testing the validity of the thesis. The milk which threw up this cream had been analysed, and found to contain water and *solids not fat* in the ratio of—

$$87{\cdot}55 \quad : \quad 9{\cdot}38$$

Cream I., as will be seen, contains water and *solids not fat* in the ratio of—

$$72{\cdot}20 \quad : \quad 8{\cdot}80$$

The theory requires that the ratio of water to *solids not fat* in the cream should be—

$$72{\cdot}20 \quad : \quad 8{\cdot}31$$

The correspondence is sufficiently near to show that the theory holds in this instance.

The case of Creams II. and III. we will deal with presently. Passing on to Cream IV., we have the ratio of water to *solids not fat*—

$$60{\cdot}17 \quad : \quad 6{\cdot}81$$

Theory requires

$$60{\cdot}17 \quad : \quad 6{\cdot}43$$

In Cream V. the ratio is—

53·62 : 8·21

and it should be

53·62 : 5·63

which does not agree very well.

In Cream VI., the ratio is—

50·0 : 6·1

It should be

50·0 : 5·36

which is a sufficiently close approximation.

In Creams II. and III., which were drawn off the same sample of milk (which, by the way, was the rich town-fed milk), and which differ by being drawn after different periods had elapsed, we have—

In Cream II. the ratio is—

71·2 : 14·7

In Cream III.—

66·36 : 14·77

the ratio required by the theory being

85·93 : 10·07

It would therefore appear that the rich town-fed milk is apt to throw up a little caseine along with the fat. In general, however, the cream consists simply of fat *plus* a solution of caseine, milk-sugar, and ash, of just the same strength as existed in the milk which gave the cream. The exception in favour of the cream given by town-fed milk must even be received with extreme caution by reason of the great difficulty of the cream-analysis, and the certainty that the whole experimental error falls on the determination of *solids not fat*, and that any imperfection in the analysis tends to enlarge the *solids not fat*.

There is far more difficulty in drying a cream-residue than in drying a milk-residue: there is also the chance of loss of fat, and any imperfections of this kind would make *solids not fat* too high.

In this place it is proper to say that the analysis of cream is very like the analysis of milk; only that much less than five grammes should be taken for the determination of water. The cream must be weighed out—not measured. About two grammes is ample for the determination of water. The drying must be made in the water-bath, and may take as long as six or eight hours. The question is often put—Has a given specimen of cream been thickened with gum or such like material?

A very decided answer may be given in the negative if the ratio of water to *solids not fat* is that required by the solution of caseine, milk-sugar, and ash, constituting the non-fatty portion of milk.

Should there be too much *solids not fat*, then the inquiry must be made whether the excess be caseine.

Cream is sometimes suspected of being stiffened with starch; this, of course, is at once detected by testing with a little iodine, which will at once strike a blue, if any such adulteration had been practised.

CHAPTER XI.

BUTTER.

In the thickest varieties of cream there is probably incipient cohesion of the fat globules. In butter the fat has actually cohered; and it ought also to have been washed and very slightly salted. Butter is milk-fat, not indeed in a state of absolute chemical purity, but with a certain comparatively small proportion of water and a little salt.

The first point to be inquired into is, How much water may butter contain? In fresh Devonshire butter I found—

Fat	82·7
Salt	1·1
Water, and trace of organic matter .	16·2
	100·0

In Normandy butter—

Fat	82·1
Salt	1·8
Water, and trace of organic matter .	16·1
	100·0

These results agree with Mr. Way's observations; and commercial fresh butter may, accordingly, contain some 18 per cent. of water, including the touch of salt. Salt butter may apparently contain some 6 per cent. of salt. The analysis of butter is made as follows—

First, great care must be taken to get a fair sample of the lot. This is, perhaps, best done by taking two specimens, one from the edge of the butter, and another from the centre. About one gramme of butter is enough for the estimation of water. This is to be weighed into one of the little platinum dishes, and dried in the bath as if it were a milk-residue. After three hours' drying it should be weighed, and returned to the bath, and weighed at intervals of an hour till constant. The drying up of butter is tedious, like the drying up of cream. Having dried it up, the residue is to be dissolved in dry ether, filtered, and the ethereal solution evaporated to dryness, and the residue dried in the water-bath. This second drying is a very easy one.

The mineral matter is estimated by burning off the fat and weighing the residue.

The "organic matter not fat" may be estimated by difference. It may also be estimated directly. For this purpose several grammes of butter are weighed out, and dried for a short time in a platinum dish in the water-bath, and then subjected to the action of dry ether, which will dissolve out the fat and leave the rest. The ethereal solution is to be decanted off, and the residue dried up in the water-bath, weighed, and ignited, and again weighed. The difference between the two weights is the weight of the organic matter not fat.

With regard to the question of admixture of foreign fats with milk-fat, we are unable, in the present condition of our knowledge, to deal with that part of the problem.

As has been said, milk-fat is a mixture of the ethers of glycerine, which constitute the common fats. It contains, it is true, a trace of butyrine, in addition to the commoner glycerides; and it is possible that, by an extraction of the butyric acid, we might arrive at data of some value in forming a judgment of the quality of the fat. But investigation is required before that could be depended upon; and at present the chemist will act wisely in declining to pronounce on the difference between butter-fat and other fat.

In the butter-trade there are certainly two kinds of fraud which are very rife. The one is the passing off of butter of inferior flavour for butter of high flavour. The other is the making of butter take up too much water and salt.

An investigation which I had the honour of making for Government illustrates how these two descriptions of fraud are practised in the London workhouses.

I quote the report *in extenso*:—

"REPORT ON THE BUTTER SUPPLIED TO THE METROPOLITAN UNIONS.

"Good butter, as it occurs in the market, consists of 12·5 per cent. of water, 1·0 per cent. of salt, a little caseine, and the rest of butter-fats; salt butter may contain 5 per cent. of fat.

"The falsifications to which butter is liable are said to be the adulteration of it with organic substances like starch or gelatine, substances which are not fat; adulteration with fat which is not butter-fat; undue moisture, and saltness.

"In the fifty specimens of workhouse butter sent to me by Mr. F. W. Rowsell between 8th May and 7th July 1871, I have not noted any case of adulteration with starch or other organic matter which is not fat.

"The adulteration of butter-fat with foreign fats—that is to say, with fat which is not the fat of butter—is not capable of being ascertained with precision in the present state of chemical methods of analysis.

"In the instance of butter No. 6, viz., 'St. Giles-in-the-Fields (officers),' I have met with a butter in which there appears to be some foreign fat.

"The point brought out by my examination is the extraordinary way in which many of the butters have been made to take up water.

"I have also given an opinion on the quality of the butter, or its flavour. This opinion was obtained from professed butter-dealers.

"Fourteen of the butters contain an undue proportion of water, viz., Kensington, Marylebone, St. Luke's (Chelsea), Paddington (fresh), Paddington (paupers), Whitechapel (inmates), City of London (inmates), Holborn (inmates), Camberwell, Stepney (inmates), Clapham and Wandsworth (inmates), Hackney (inmates), St. George's-in-the-East (inmates), Greenwich (inmates).

"The worst case of undue wetness and saltness is 'Whitechapel (inmates),' which contains 35·6 per cent. of salt and water; and, after deducting the small quantity of organic matter which is not fat, is seen to contain only some 60 per cent. of fat.

NO.	NAME.	WATER.	SALT.	
1	St George's (Kensington Workhouse)	8·6	4·5	Rank.
2	Kensington (salt)	23·7	6·0	Wretched.
3	Marylebone	18·2	6·9	Tolerable.
4	Westminster (information refused)	...	...	...
5	St Luke's, Chelsea	14·5	3·2	Fair.
6	St Giles-in-the-Fields (officers) ...	13·2	0·7	Very rank.
7	St Giles-in-the-Fields (paupers)...	12·5	1·0	Bad.
8	Strand	9·7	2·7	Tolerably good.
9	Fulham (officers)	12·9	0·1	Very good.
10	Fulham	13·1	4·3	Good.
11	Paddington (fresh)	23·6	1·0	Rather rank.
12	Paddington (paupers)	16·5	4·9	Bad.
13	Whitechapel (officers)	12·4	1·0	Middling.
14	Whitechapel (inmates)	24·9	10·7	Very bad.
15	Mile-End Old Town (officers) ...	11·6	2·1	Good.
16	Mile-End Old Town (inmates) ...	11·5	1·2	Very fair.
17	City of London Mile-End Workhouse (officers)	13·7	1·1	Good.
18	City of London Mile-End Workhouse (inmates)	20·0	2·6	Bad.
19	Shoreditch (officers)	13·2	1·0	Good.
20	Shoreditch (inmates)	15·3	4·7	Bad.
21	Bethnal Green (officers) ...	11·7	...	Good.
22	Bethnal Green (inmates) ...	11·3	2·4	Middling.
23	St Pancras (officers)	12·8	1·0	Bad.
24	St Pancras (inmates)	12·2	5·1	Very bad.
25	Holborn (officers)	8·2	2·8	Good.
26	Holborn (inmates)	19·7	7·0	Middling.
27	Lambeth (officers)	13·3	1·5	Bad.
28	Lambeth (inmates)	13·2	2·1	} Exceedingly
29	Camberwell	14·7	8·1	} bad.
30	Islington	9·8	4·4	Tolerable.
31	Poplar (officers)	12·0	0·9	Middling.
32	Poplar (inmates)	12·9	6·3	Very bad.
33	Stepney (officers)	12·7	...	Middling.
34	Stepney (inmates)	16·5	0·7	Nasty.
35	St Olave's (officers)	11·3	2·3	Pretty good.
36	St Olave's (inmates)	14·3	3·5	Fair.
37	Hampstead (officers)	11·6	0·1	Good.
38	Hampstead (inmates)	12·2	0·4	Fair.
39	Wandsworth & Clapham (officers)	13·3	1·7	Very good.
40	Wandsworth & Clapham (inmates)	15·3	7·3	Bad.
41	St Saviour's (officers)	11·9	0·5	Very bad.
42	St Saviour's (inmates)	12·6	4·4	Fair.
43	Hackney (officers)	14·2	1·1	Good.
44	Hackney (inmates)	16·6	4·7	Tolerable.
45	St George's-in-the-East (officers)	9·9	3·5	Good.
46	St George's-in-the-East (inmates)	15·4	5·6	Bad.
47	Greenwich (officers)	10·9	1·7	Good.
48	Greenwich (inmates)	19·4	5·9	Fair.
49	Lewisham (officers)	12·1	0·4	Tolerable.
50	Lewisham (inmates)	10·7	5·4	Good.

"J. ALFRED WANKLYN.

"LONDON, 11*th July* 1871."

Since the first edition of this book was written great advance has been made in the analysis of butter.

Hehner and Angell have shown that whereas the common fats yield about 95 per cent. of insoluble fatty acids when they are saponified, butter-fat yields only 87 to 88 per cent. On this observation they have founded an excellent method of dealing with the question of the adulteration of butter.

A suitable quantity of dry butter-fat is weighed out, mixed with alcohol and about half its weight of solid potash, and heated in the water-bath. When the saponification is complete water and excess of dilute sulphuric acid are added, and in that way the insoluble fatty acid is obtained. It is washed, and got on a filter, removed from the filter to a suitable vessel, dried, and weighed. If the fat be common fat, the insoluble fatty acids will be about 95 per cent. of the dry fat, whilst butter-fat will yield 87 to 88 per cent.

Another method is due to Mr. Bell, of Somerset House, who has observed that melted butter-fat is of higher specific gravity than common fats.

The method which I recommend is founded on the unique behaviour of butter towards alcohol and alcohol and potash, and is the conjoint contribution of Mr. William Fox and myself. Boiled with alcohol, butter gives no butyric ether. Boiled with alcohol and potash, butter yields butyric ether, which admits of being distilled off and titrated. The yield of butyric ether from pure butter is 3 per cent.*

* *Vide*, "The Analyst," 1884, vol. ix. page 73.

CHAPTER XII.

CHEESE.

Cheese consists mainly of caseine, milk-fat, a little salt and phosphate of lime, and water. It is, as is well known, prepared by subjecting milk to the action of rennet, which coagulates it, and then pressing the curds, which, after treatment, constitute the cheese. There is great variation in the composition of cheese.

According to Payen, the water ranges from 30 to 62 per cent.; the fat, according to the same chemist, appears to vary from about 20 to about 30 per cent. The percentage of caseine appears to range from 15 to 35, and the mineral matter from $4\frac{1}{4}$ to 7.

The analysis of cheese is managed as follows:—The water is determined by taking about one gramme, and drying it in the water-bath in a small platinum dish (one of the little dishes used for milk-residues will answer very well) until it ceases to lose in weight. After the determination of the water, the residue may be ignited, and the ash weighed.

For the determination of fat and caseine, it is well to take a larger quantity of cheese. About ten grammes is a convenient quantity. The cheese should be weighed out, having been first cut up into small pieces, and then introduced into a small flask. It is then boiled with dry ether, and the resulting ethereal solution of the fat is decanted off; the boiling and decantation is repeated twice, and, finally, the ethereal solutions are carefully evaporated down in a platinum dish, and the fat which is left behind is dried at 100° C. and weighed.

In the above operation great care must be taken to exhaust thoroughly with ether; the mass may be got out of the flask and powdered up in a mortar if necessary. It is also well to moisten with a few drops of strong alcohol before adding the ether. Having, as aforesaid, obtained from the cheese an ethereal solution of the fat, and having disposed of this ethereal solution, we return to the mass which refuses to dissolve in the ether. This consists of caseine, possibly of milk-sugar as well, and certainly of salt and phosphate of lime. It is to be treated first with strong alcohol, and then washed with boiling water, and then dried in a platinum dish. The dry residue (which consists of caseine and phosphate of lime or ash) is then weighed, ignited, and weighed again: the difference, *i.e.*, the loss on ignition, is the caseine.

In order to determine the milk-sugar, the alcoholic and aqueous solutions are to be evaporated to dryness, the residue weighed and ignited, and the loss on ignition will include the sugar.

In analysis of cheese it is necessary that a caution should be given respecting the large amount of ash in cheese. As much as 7 per cent. of ash may be present in cheese, without adulteration with mineral matter having been practised.

It has been stated that oxide of lead has been found in cheese. Should any such case arise, it is very easily dealt with. The cheese-ash (which, in such a case, should be got in a porcelain crucible, since lead attacks platinum) is tested for lead by means of sulphuretted hydrogen.

CHAPTER XIII.

KOUMISS.

IN addition to cream, butter, and cheese, the derivatives of milk include whey and butter-milk, which latter do not call for any special notice. There is, however, another derivative of milk, which ought not to be passed over. Milk can be got to ferment and yield a sort of milk-wine, which goes by the name of koumiss. In Tartary, where mares' milk is used for the purpose, the drink which results is of great importance as an article of nourishment for the population. The use of koumiss is said, moreover, to impart immunity from phthisis, and an attempt is being made in this country to produce an English koumiss for the use of patients whose nutrition is impaired. It is hoped that koumiss will prove to be at least as efficacious as cod-liver oil is believed by many people to be.

The following analyses of koumiss, manufactured in London by E. Chapman & Co., were made in my laboratory.

It should be mentioned, that inasmuch as mare's milk contains a larger proportion of sugar than cows' milk, an addition of a little sugar is made to the milk before it is set to ferment.

In "full koumiss," forty-eight hours old, which had a specific gravity of 1·032 at 67° Fahr., I found—

In 100 parts by weight—

Water	87·32
Alcohol	1·00
Carbonic acid	0 90
Solids	10·78
	100·00

The 10·78 parts of solids contained—

Caseine	2·84
Lactose and lactic acid	6·60
Fat	0·68
Ash	0·66
	10·78

Some of the same sample of koumiss, after having been kept for six days at 62° Fahr., contained in 100 parts by weight—

Water	88·47
Alcohol	1·60
Carbonic acid	1·50
Solids	8·43
	100·00

A determination of the proportion of lactic acid in this koumiss, on its tenth day, or eight days older than when first examined, showed 1·1 per cent. When thirty-five days old, this koumiss had a specific gravity of 1·023, and contained in 100 parts by weight—

Water	89·16
Alcohol	1·80
Carbonic acid	1·50
Solids	7.54
	100·00

The solids consisting of—

Caseine	2·57
Lactose and lactic acid	3·82
Fat	·50
Ash	·65
	7·54

To begin with, koumiss contains about the same percentage of solids as skimmed milk; but, as will be observed on inspecting these analyses, and as might have been expected, koumiss, as it grows older, loses sugar and total solids.

It is claimed for koumiss that it presents the caseine in a form specially assimilable by invalids, and that koumiss will sometimes nourish persons when nothing else will nourish. It is not the place, in a work like the present, to discuss how far these claims are made good, but it is right to call attention to the fact of such claims having been put forward.

CHAPTER XIV.

CONDENSED AND PRESERVED MILK.

This preparation of milk, which is now much in vogue, consists of milk which has been evaporated down *in vacuo.*

When it is intended to keep for any lengthened period, it is mixed with a considerable proportion of pure cane-sugar.

When it is not required to keep for longer than two or three days, it is simply tinned, and not mixed with sugar.

The condensed milk is strictly what its name signifies; for, on being mixed with the appropriate quantity of water, it regenerates milk. The preserved milk, too, regenerates milk on being diluted; only it is sweet, owing to the sugar employed in the preservation.

A year ago, a report was spread that these preserved milks were preserved skim-milk, and not preserved new milk. This report, which was spread by a Government official who ought to have known better, is a most undeserved calumny.

I have myself examined the principal brands of preserved and condensed milk which are in the London market, and find that the milk which had been condensed, or condensed and preserved, had been charged with its due proportion of fat.

In the Anglo-Swiss I found 9·9 per cent. of fat. In the product of the English Condensed Milk Company (Limited), I found 10·4 per cent. of fat in the preserved milk, and 12·11 per cent. in the condensed milk.

The method of analysing condensed or preserved milk is that recommended for cheese. Great care must be taken in the estimation of the fat. Disintegration with alcohol or actual pulverisation in a mortar are to be recommended, in order to bring the ether completely into relation with the mass. The following analyses of the produce of the English Condensed Milk Company may be of interest:—

PRESERVED MILK.

In 100 parts by weight—

Water	20·5
Fat	10·4
Caseine	11·0
Ash	2·0
Cane and milk-sugar	56·1
	100·0

CONDENSED MILK.

Water	51·12
Fat	12·11
Caseine	13·64
Milk-sugar	20·36
Ash	2·77
	100·0

CHAPTER XV.

POISONOUS MILK AND MILK-PANICS.

It is known that violent mental emotion exercises an unfavourable influence on the secretion of the mammary gland; and a fit of anger has rendered the milk of the human mother poisonous to the child. No doubt the milk of the cow is more or less liable to similar influences; and cows which are giving milk should not be driven or harassed in any way. Diet, too, has an effect on the quality of the milk; a purgative administered to the mother often taking effect on the child. Poisonous herbs fed on by the cow contaminate the milk; and a very well-known example in point is afforded by turnipy butter, which derives its very objectionable (though not poisonous) properties from turnips on which the cow has happened to feed. All this tends to show the importance of attending to the health of milk-giving cows, and to the kind of fodder on which they are fed.

Milk, after it has been yielded by the animal, may suffer contamination at a later stage. A case is recorded where, in the process of milking, which was performed by persons recovering from scarlet fever, the infection of scarlet fever was conveyed by the milk to children who drank it. This is, I believe, authentic enough.

In addition to these genuine instances of milk-poisoning, a very subtle kind of poisoning has been described. It has been said that, if a very minute quantity of water from a foul well be mixed with a very large quantity of milk, the whole mass of milk will become poisonous. And, as is well known, considerable alarm has been created in the west-end of London, by a report that the milk purveyed by a certain milk-company had occasioned an outbreak of typhoid fever in Marylebone, and the parishes adjacent to Marylebone.

It is, however, important to record that the result of investigation has been to demonstrate the groundlessness of these alarms. The returns of the Registrar-General, which are now before the public, show that Marylebone has seldom been so free from typhoid fever as during the period of the supposed epidemic.

The history of this supposed epidemic of typhoid fever, or, as it would be more correctly designated, the history of the milk-panic of 1873, is very instructive in many ways.

Early in August 1873, several children of an eminent west-end physician were ill of typhoid fever, and their father attributed the disease to the milk which they took. The doctor's family was supplied with milk by the Dairy Reform Company. On communicating his suspicions to neighbouring medical men, and to the medical officer of health for the district, a number of cases of alleged typhoid were found among customers of the same dairy, a strangely large proportion of these cases occurring in the families of medical men. It was said that, naturally enough, the superior knowledge of medical men was the explanation of the apparent preference of the disease for their families, and that by-and-by the anomaly would disappear when the multitudes of unrecognised cases in non-medical families became sufficiently serious to force recognition of their real nature. The physician and the medical officer of health (in a most public-spirited manner, as it was called) addressed a peremptory order to the directors of the milk-company to stop selling milk; the fears of the physician even reached the Local Government Board, and an official investigation was ordered.

Meanwhile the press took up the subject, and the medical papers and the non-technical newspapers vied with one another in sensational descriptions of the "Outbreak of Typhoid Fever," its source, and the wickedness or recklessness of the milk-company which had caused it.

At the outset of the panic, the leading journal published a list of twenty-three households wherein inmates were said to have been poisoned by the Dairy Reform Company. With the assistance of my friend Mr. Cooper, I took the trouble to inquire into some of these cases. In one of these households there was no one ill, and there had been no one ill. In another household, there had been only a little summer diarrhœa. In a third, the lady had been taken ill in Munich, where typhoid fever is known to be rife. In a fourth, where the servants were affected, the water in the kitchen was bad, the general supply to the house being good. The servant had, moreover, been a day's journey into the country during the very hot weather, and had been overheated. I did not pursue the investigation further.

The official report on the condition of the farms whence the milk-company derive their supply of milk has not yet been published. A gentleman who attended on behalf of the Dairy Reform Company has, however, written to *The Times* newspaper a letter purporting to give an outline of the conclusions arrived at by the Commission. From this letter we gather that at the time of the inquiry there were no cases of typhoid on any of the farms, and that there had been no recent cases. Instead, however, of calling public attention to that most satisfactory result of the inquiry, the writer of the letter dwelt upon a very doubtful case which had occurred on one of the farms at a rather remote period. The supposed epidemic was alleged to be at its height about the 10th of August, and before the beginning of August nothing had been heard of any epidemic. On the supposition of infection from one of the farms, we should hardly look for the case before the beginning of July. The case, however, to which the writer of the letter directed attention dated as far back as before the 8th of June. The case in question was that of the farmer who had occupied one of the farms, and who died on the 8th of June. Even the nature of his illness is involved in doubt. The man's death, indeed, is entered on the register as caused by heart-disease, from which he had been known to have suffered for at least a year; and the suddenness of his death is quite in accordance with the register. Some few weeks before his death he had an attack of diarrhœa of a suspicious character, and that circumstance was seized upon as a reason for setting down his case as one of typhoid fever. It is, however, hard to believe that the excreta from this man can have poisoned the farm-well, and that the water from that well should have poisoned the milk which was sent to London, without poisoning any one on the farm; and the wonder becomes the greater since the water from the well was occasionally, though not usually, employed for domestic purposes.

As already mentioned, the reported case of typhoid occurred very much too early to account for what was called the London outbreak. It is very curious to observe that the termination of the outbreak did not accord with the theory. That which was designated the "infected milk" ceased to be supplied to London on the 11th of August, and forthwith —within two or three days—the epidemic was reported to have declined. The period of incubation in typhoid fever is ten days or thereabouts; therefore the stoppage of the poisoning on the 11th should not have been felt till towards the 21st.

It has been mentioned that when the returns of the Registrar-General were published, the mortality in Marylebone from typhoid-fever was found to have been lower than usual. The following are the returns, week by week, embracing the whole period of the panic. Population of Marylebone, 159,254.

The deaths from typhoid fever in Marylebone were as follows:—

During week ending	5th July	0
" "	12th "	1
" "	19th "	2
" "	26th "	0
" "	2d August	1
" "	9th "	1
" "	16th "	3
" "	23d "	2
" "	30th "	2
" "	6th September	2
	Total during the ten weeks	14

Being at the rate of rather less than one per 100,000 per week.

A poison which does not poison you if you take it in aqueous solution, but poisons a whole township when that same aqueous solution is diluted with milk a hundred or a thousand fold, and whose period of incubation is sometimes two months and sometimes three days, according to the exigencies of your case, must be singular indeed. And when such a poison seems to have ravaged a whole parish, it marks its ravages most appropriately by a diminution in the death-rate.

APPENDIX.

MILK-ANALYSIS.

To the Editor of the "Chemical News."

SIR,—In issuing a Second Edition of my Treatise on Milk-Analysis, I feel called upon to make known my views on the present condition of milk-analysis in this country, and as one of my earliest papers on the subject was published in the *Chemical News* about fourteen years ago, I send you my present contribution.

In constructing a system of milk-analysis, I was mindful that milk is a complex organic fluid, and that its constituents must be fragile, and that in submitting it to analytical processes there was the danger of setting up decomposition.

When I sought to obtain the total milk-solids by the process of evaporating off the water and drying the residue, it was necessary to guard against mistaking the actual water existing in the milk for water which might arise as a decomposition product. Under the influence of this idea, I was led to seek the quickest way of obtaining the total solids, and found that a three hours' exposure to a temperature of 100° C. in a suitable platinum vessel, will deprive 5 grammes of milk of all its water, and reduce it to the condition of dry milk-solids. Very numerous experiments warrant me in asserting that the total milk-solids obtained in that manner are a constant quantity, which, in point of constancy, will challenge comparison with the best constants in analytical chemistry. My system of milk-analysis is based upon this constant, and rests on it as on a rock.

For some years milk-analysis, very much in the form in which I had cast it, was much practised in this country, and has been resorted to in the proceedings under the Acts for the suppression of the adulteration of food.

Many attempts have been made to discredit it, especially within the last four years; and its author, as is notorious, has, for the most part, abstained from taking any part in the discussions which have arisen.

There are two chief causes why, just at the present time, milk-analysis has declined in public estimation. One of these causes is that those analysts who practise it have not adhered with sufficient closeness to the details of the method as laid down by its author. The other cause is the appointment of the authorities of Somerset House as a sort of court of reference in cases arising under the Sale of Food and Drugs Act.

According to the directions given in the Treatise, a milk-residue is to be obtained by drying up 5 grammes, or 5 c. c. of milk, for three hours; and I lay particular stress on the full time being allowed. In the pages of *The Analyst* for the year 1882, Mr. Hehner describes the method to consist in drying 5 grammes of the milk for two and a half to three hours. Sometimes analysts alter the scale, taking 10 grammes instead of 5 grammes for the solid residue; and even the temperature of drying has been altered—instead of 100° C., I have known 110° C. to be employed. The substitution of the water-oven for the water-bath is sometimes made.

I disapprove of all these alterations, and have to remark that, under such treatment, discrepancies are inevitable.

In my Treatise the "solids not fat" are arrived at by the arithmetical operation of subtracting the quantity of fat from the quantity of total solids. It may seem a small point—to insist upon that manner of arriving at the "solids not fat" in preference to the direct operation of weighing the "solids not fat;" but I believe that much uncertainty has arisen from the substitution of the direct for the indirect measurement of "solids not fat."

With regard to the determination of the fat, I do not see any reason to alter the method laid down in my book; and I would make the remark, that the extra 0·2 per cent. of fat with which the employment of the Soxhlet apparatus is credited, may possibly be a product arising from the metamorphosis of the caseine.

In constructing the system of milk-analysis, I had before my eyes the necessity that the system should be practicable as well as logically consistent. I felt, too, that simplicity and rapidity of execution would commend it. That it is simple beyond compare, and that it is quick, is a matter of common knowledge.

In three and a half hours a good operator is able to make the whole analysis, and to fill up the following form:—

In 100 c. c. of milk—

	Grammes.
Total solids	$= x$
„ fat	$= y$
Solids not fat (calculated) . .	$= x - y$
Ash	$= z$

In reading the criticisms of the milk-analysis—I hope I may be pardoned for saying so—I have been amused. My critics appear to imagine that milk is a fluid of simple composition, and that in point of simplicity it resembles an aqueous solution of two or three simple mineral salts; and appear to regard paying attention to the complexity of milk as an unscientific procedure. My critics, who look upon milk as a comparatively simple fluid, recommend complicated and tedious analytical processes which they say are scientific. I, who hold that the composition of milk is pre-eminently complex, resort to the simplest of analytical methods.

The various suggestions which have been made for the modification of milk-analysis—the suggestion to dry for six hours instead of for three or three and a half hours; the suggestion to mix the milk with sand, or to spread it out on blotting-paper; the suggestion to submit the "solids not fat" to two dryings instead of one; the suggestion to resort to the Soxhlet digestion with ether, instead of the simpler treatment; all these suggestions tend in one direction, viz., towards the destruction of the "solids not fat," which, when milk-analysis left my hands fourteen years ago, were shielded from all harm with most zealous care. The adoption of these suggestions at once lowers the milk standard from 9·3 to 8·5; and the principles which dictate the adoption of these suggestions, degrade milk-analysis to the condition in which I found it before the year 1871.—Yours, &c.,

J. ALFRED WANKLYN.

LONDON, 25*th January* 1886.

THE END.

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